National Aeronautics and Space Administration

Space Life and Physical Sciences
Briefing to the Research Subcommittee

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February 24, 2014

Where does research come from?

- Human Research Program research content is driven by identified risks to crew health and performance
- Biological and Physical Sciences research content is largely driven by advisory recommendations

Human Health and Performance Risks By Element

Risks Reviewed by the Institute of Medicine

SHFH Risks

Risk of Error Due to Inadequate Information

Risk Associated with Poor Task Design

Risk of Adverse Health Affects from Dust Exposure

Risk Factor of Inadequate/Inefficient Food System

Risk of Reduced Safety and Efficiency Due to Poor Human Factors Design

Risk of Crew Adverse Health Due to Alterations in Host-microorganism Interactions

BHP Risks

Risk of Behavioral and Psychiatric Conditions

Risk of Performance Errors Due to Sleep Loss, Circadian Desynchronization, Fatigue and Work Overload

Risk of Performance Errors Due to Poor Team Cohesion and Performance, Inadequate Selection/Team Composition, Inadequate Training, and Poor Psychosocial Adaptation

Space Radiation Risks

Risk of Radiation Carcinogenesis

Risk of Acute Radiation Syndromes Due to Solar Particle Events

Risk of Acute or Late Central Nervous System Effects from Radiation Exposure

Risk of Degenerative Tissue or other Health Effects from Radiation Exposure

HHC Risks

Risk of Accelerated Osteoporosis

Risk of Orthostatic Intolerance During Re-Exposure to Gravity

Risk Factor of Inadequate Nutrition

Risk of Compromised EVA Performance and Crew Health Due to Inadequate EVA Suit Systems

Risk of Impaired Performance Due to Reduced Muscle Mass, Strength and Endurance

Risk of Bone Fracture

Risk of Intervertebral Disc Damage

Risk of Renal Stone Formation

Risk of Cardiac Rhythm Problems

Risk of Reduced Physical Performance Capabilities Due to Reduced Aerobic Capacity

Risk of Crew Adverse Health Event Due to Altered Immune Response

Risk of Impaired Ability to Maintain Control of Vehicles and Other Complex Systems

Risk of Therapeutic Failure Due to Ineffectiveness of Medicine

Risk of Microgravity-induced Visual Impairment/Intracranial Pressure (VIIP) (added after IOM review)

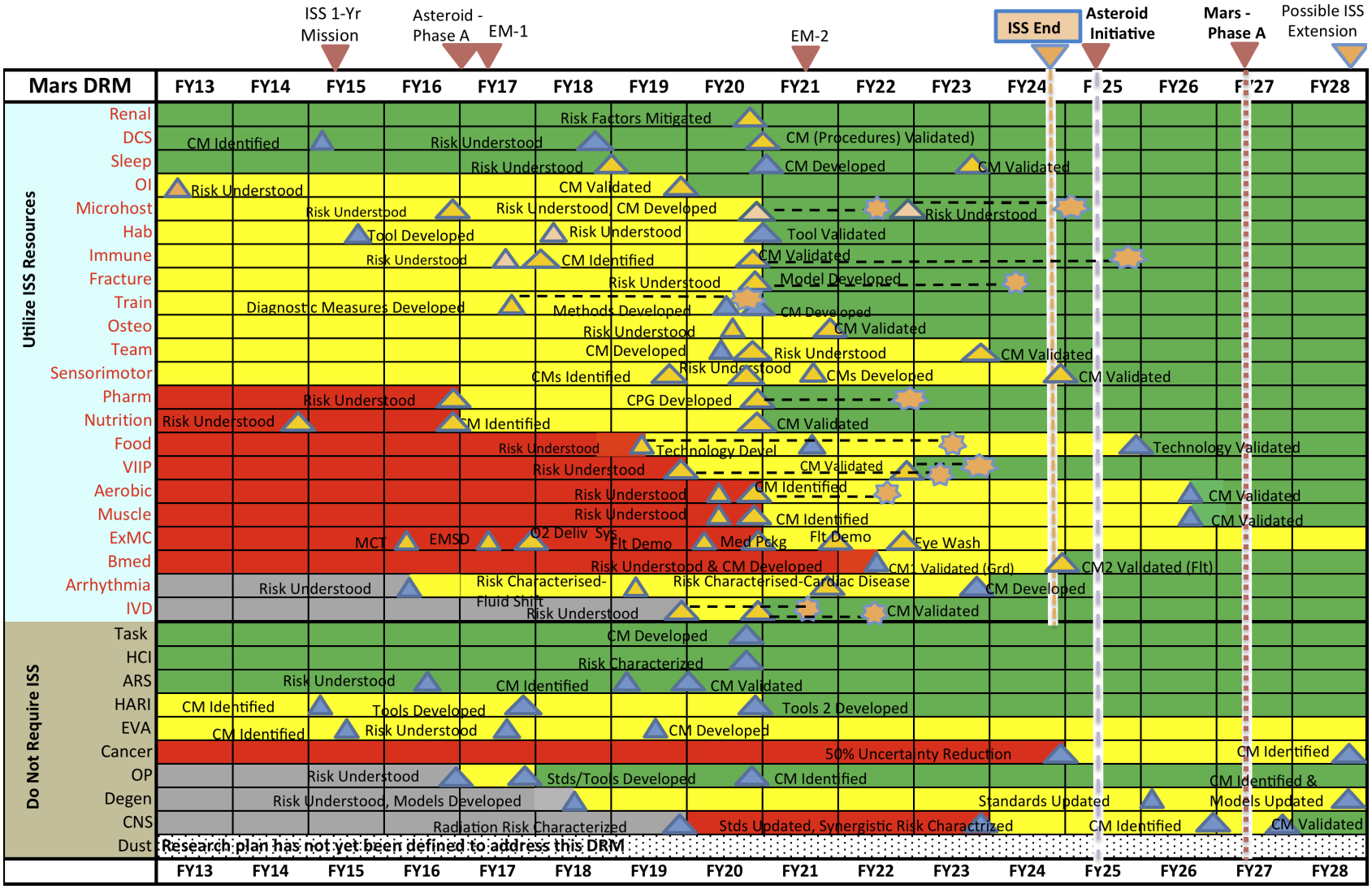
Risk of Injury from Dynamic Loads (added after IOM review)

ExMC Risks

Risk of Inability to Adequately Treat an ill or Injured Crew Member

Human Exploration and Operations

Human Research Program Integrated Path to Risk Reduction



HRP Risk — Requires ISS

HRP Risk — ISS Not Required

Research Rating

Unacceptable | Acceptable | Controlled | Insufficient Data

Milestone uses ISS

Milestone projection due to flight subject limitations

Full Risk Titles & Acronyms for HRP Integrated PRR Chart

Aerobic	Risk of Reduced Physical Performance Capabilities Due to Reduced Aerobic Capacity
Arrhythmia	Risk of Cardiac Rhythm Problems
ARS	Risk of Acute Radiation Syndromes Due to Solar Particle Events
Bmed	Risk of Adverse Behavioral Conditions and Psychiatric Disorders
Cancer	Risk of Radiation Carcinogenesis
CNS	Risk of Acute or Late Central Nervous System Effects from Radiation Exposure
DCS	Risk of Decompression Sickness
Degen	Risk of Degenerative Tissue or other Health Effects from Radiation Exposure
Dust	Risk of Adverse Health Effects of Exposure to Dust and Volatiles During Exploration of Celestial Bodies
EVA	Risk of Compromised EVA Performance and Crew Health Due to Inadequate EVA Suit Systems
ExMC	Risk of Unacceptable Health and Mission Outcomes Due to Limitations of In-flight Medical Capabilities
Food	Risk of Performance Decrement and Crew Illness Due to an Inadequate Food System
Fracture	Risk of Bone Fracture
Hab	Risk of an Incompatible Vehicle/Habitat Design
HARI	Risk of Inadequate Design of Human and Automation/Robotic Integration
HCI	Risk of Inadequate Human-Computer Interaction
Immune	Risk of Crew Adverse Health Event Due to Altered Immune Response
IVD	Risk of Intervertebral Disc Damage
Microhost	Risk of Adverse Health Effects Due to Alterations in Host-Microorganism Interactions
Muscle	Risk of Impaired Performance Due to Reduced Muscle Mass, Strength and Endurance
Nutrition	Risk Factor of Inadequate Nutrition
Occupant Protection (OP)	Risk of Injury from Dynamic Loads
OI	Risk of Orthostatic Intolerance During Re-Exposure to Gravity
Osteo	Risk of Early Onset Osteoporosis Due to Spaceflight
Pharm	Risk of Clinically Relevant Unpredicted Effects of Medication
Renal	Risk of Renal Stone Formation
Sensorimotor	Risk of Impaired Control of Spacecraft, Associated Systems and Immediate Vehicle Egress due to Vestibular / Sensorimotor Alterations Associated with Space Flight
Sleep	Risk of Performance Errors Due to Fatigue Resulting from Sleep Loss, Circadian Desynchronization, Extended Wakefulness, and Work Overload
Task	Risk of Inadequate Critical Task Design
Team	Risk of Performance Decrements due to Inadequate Cooperation, Coordination, Communication, and Psychosocial Adaptation within a Team
Train	Risk of Performance Errors Due to Training Deficiencies
VIIP	Risk of Spaceflight-Induced Intracranial Hypertension/Vision Alterations

CM	Countermeasure
CPG	Clinical Practice Guidelines
DSH	Deep Space Habitat
EM-1,-2	Exploration Mission -1,-2, Multi-Purpose Crew Vehicle
EMU	Extravehicular Mobility Unit
EMSD	Exploration Medical System Demonstration
EVA	Extravehicular Activity
ExMC	Exploration Medical Capabilities
Exp	Exploration
HRP	Human Research Program
IRP	Integrated Research Plan
ISS	International Space Station
MCT	Medical Consumable Tracking
“N”	investigation subject
O2	Oxygen
PCN	Page Change Notice
PRR	Path to Risk Reduction
Rev	Revision
SRR	System Requirements Review

Human Research Program (HRP)
Research Rating Definitions (from HRP-47052, Rev F)

Rating: Controlled* (C*) - Green

A risk is deemed to have a research rating of ***Controlled*** if based on available evidence, the projected mission architecture (with assumptions on DRM-specific vehicle design and operations constraints) meet existing standards for maintaining crew health and performance and countermeasures exist to control the risk. Continued research or technology development will improve capabilities, provide additional trade space to support meeting crew health standards or ensure that vital Agency core competencies are accessible.

Context: The scientific, operational and clinical evidence for the risk and current available mitigations and countermeasure capabilities demonstrate that the Agency can meet the existing standards for maintaining crew health and performance during all phases of the mission. Research has provided at least one solution capability to address the risk. Additional research or technology development could further reduce risk by enhancing understanding and offering different options to increase engineering and operational efficiencies, make the best use of unique assets such as ISS in optimizing risk posture, and maintain vital Agency core competencies.

Rating: Acceptable* (A) - *Yellow

A risk is deemed to have a research rating of ***Acceptable*** if based on available evidence, the projected mission architecture (with assumptions on DRM-specific vehicle design and operations constraints) likely provides the capability to meet existing standards for maintaining crew health and performance but the risk is not fully controlled. The remaining level of uncertainty would likely lead the Agency to accept a higher than expected level of risk to crew health and performance during some phases of the mission. Continued research or technology development is expected to improve capabilities or substantiate crew health standards.

Context: The scientific, operational and clinical evidence for the risk and current available mitigation and countermeasure capabilities demonstrate that the Agency can likely meet existing standards for maintaining crew health and performance during some, but not all phases of the mission. Additional research or technology development may further improve the risk research rating to achieve a *Controlled* rating.

Rating: Unacceptable* (U) - *Red

A risk is deemed to have a research rating of ***Unacceptable*** if based on available evidence, the projected mission architecture (with assumptions on DRM-specific vehicle design and operations constraints) will not provide the capabilities required to meet existing standards for maintaining crew health and performance during all phases of the mission. Therefore, research is required to acquire necessary information and develop necessary capabilities and countermeasures to arrive at an acceptable risk posture.

Context: The scientific, operational and clinical evidence for the risk and current available mitigations and countermeasure capabilities do not adequately demonstrate the capability of the Agency to meet existing standards to protect and/or maintain crew health and performance during all phases of the mission. The inadequacy and uncertainty in the risk mitigation capabilities and countermeasures will require additional data and/or mitigation strategies to be developed through the research performed by the HRP.

Rating: Insufficient Data* (I) - *Gray

A risk is deemed to have a research rating of ***Insufficient Data*** if there is not enough available evidence to assess whether the projected mission architecture (with assumptions on DRM-specific vehicle design and operations constraints) can meet existing standards for crew health and performance or if such standards need to be developed. Research is required to further understand and define the risk to the point that its research rating can be determined by HRP to controlled, acceptable or unacceptable. This rating is primarily for new risks before a research rating can be determined.

Context: The scientific, operational and clinical evidence for the risk and current mitigation and countermeasures capabilities are inadequate to allow the assessment of the ability of the mission architecture and/or mission characteristics to support crew health and performance standards. Additional research is expected to support determination of a new research rating.

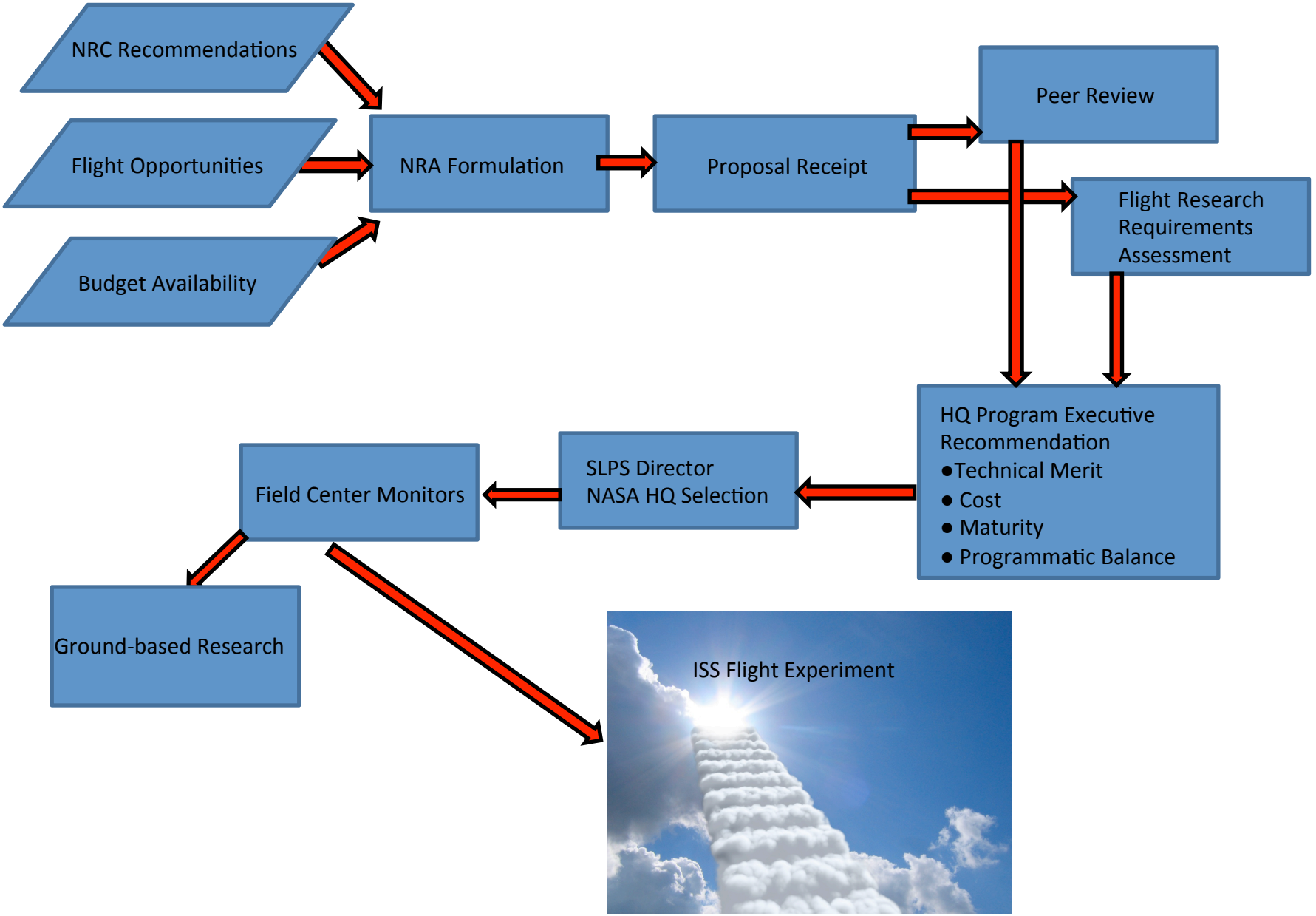
NRC Decadal Recommendations

TABLE 13.2 Highest-Priority Recommendations That Provide **High** Support in Meeting Each of Eight Specific Prioritization Criteria

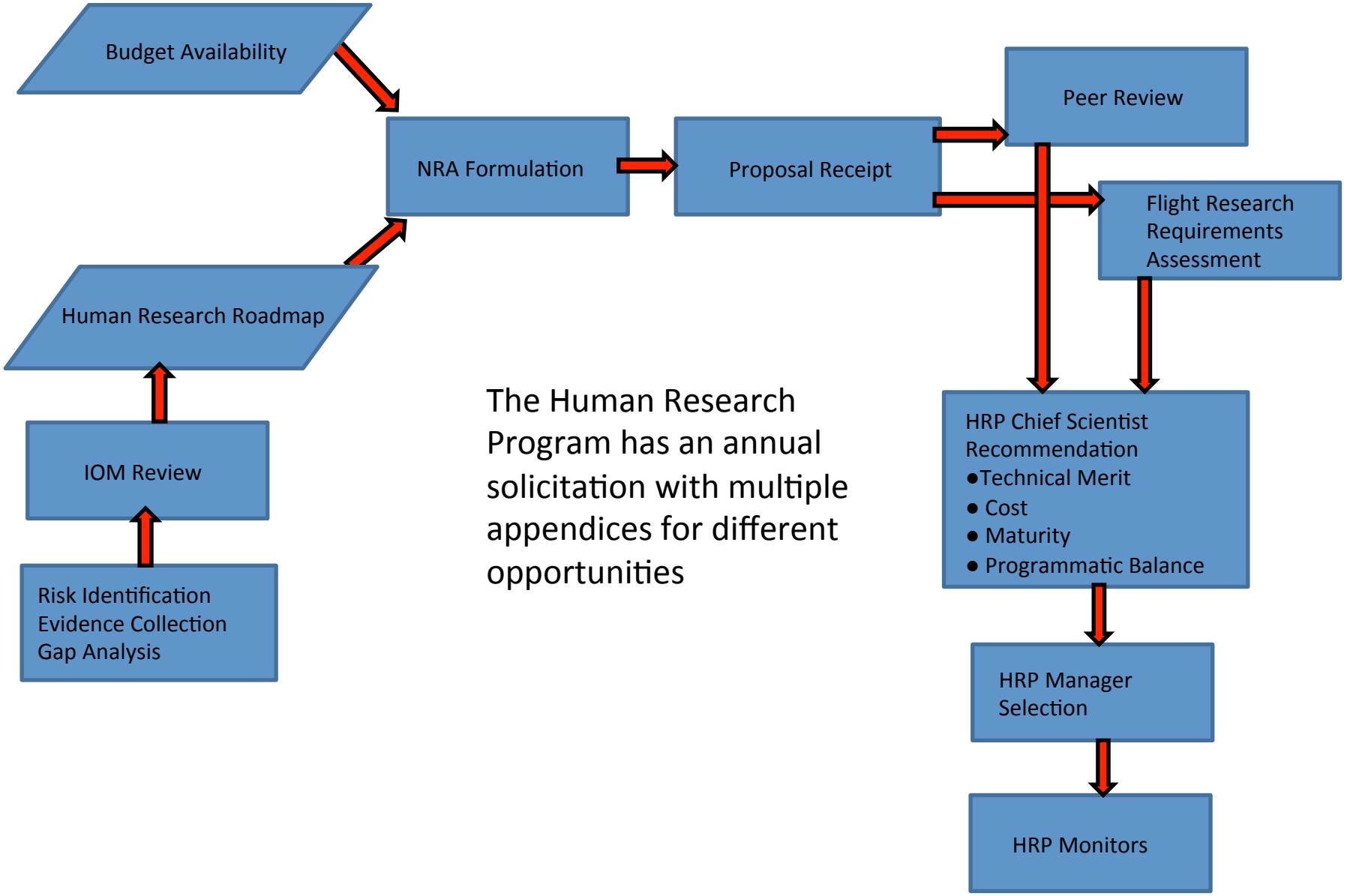
	<----------Prioritization Criteria---------->							
	(1) Positive Impact on Exploration Efforts, Improved Access to Data or to Samples, Risk Reduction	**(2)** Potential to Enhance Mission Options or to Reduce Mission Costs	**(3)** Positive Impact on Exploration Efforts, Improved Access to Data or to Samples	**(4)** Relative Impact Within Research Field	**(5)** Needs Unique to NASA Exploration Programs	**(6)** Research Programs That Could Be Dual-Use	**(7)** Research Value of Using Reduced-Gravity Environment	**(8)** Ability to Translate Results to Terrestrial Needs
Life Sciences	P2, P3, B1, B2, B3, B4, AH1, AH2, AH3, AH5, AH6, AH7, AH8, AH9, AH10, AH11	P3, B1, B2, B3, B4, AH6, AH9, AH10, AH11	P3, B4, AH1, AH2, AH3, AH5, AH6, AH7, AH8, AH9, AH10, AH11	P1, P2, B3, B4, AH9, AH10, AH11, AH16	P1, P2, P3, AH1, AH2, AH3, AH4, AH5, AH6, AH7, AH8, AH9, AH10, AH11, AH16	B1, B2, B3, B4, AH1, AH2, AH3, AH4, AH5, AH6, AH7, AH9, AH10	P1, B1, B4, AH12, AH16	B1, B2, B3, B4, AH1, AH2, AH3, AH4, AH5, AH6, AH7
Translational Life Sciences	CCH2, CCH4, CCH7	CCH2, CCH4, CCH6, CCH7	CCH2, CCH4, CCH6, CCH7, CCH8	CCH2, CCH6	CCH1, CCH2, CHH3, CCH6, CCH7, CCH8		CCH1, CHH2, CHH3, CCH7, CCH11	
Physical Sciences	AP1, AP4, AP6, AP8, AP11	AP1, AP2, AP10, AP11	AP1, AP2, AP3, AP10, AP11	FP1, FP2, FP3, AP5, AP7, AP8, AP9	AP1, AP2, AP3, AP4, AP6, AP11	AP7, AP8, AP9, AP10	FP1, FP2, FP3, FP4, AP1, AP2, AP5, AP6, AP7, AP9	AP1, AP2, AP7, AP8, AP9
Translational Physical Sciences	TSES1, TSES2, TSES3, TSES14	TSES1, TSES3, TSES5, TSES10	TSES14		TSES2, TSES3, TSES4, TSES5, TSES6, TSES7, TSES12, TSES13, TSES14, TSES 16	TSES10, TSES11, TSES12	TSES1, TSES2, TSES3, TSES4, TSES5, TSES12, TSES13, TSES14, TSES15, TSES16	TSES10

NOTE: Identifiers are as listed in Table 13.1 and correspond with the recommendations listed there and also presented with clarifying discussion in Chapters 4 through 10.

How SLPS Selects Research –
Traditional Approach in Space Biology and Physical Sciences



How SLPS Selects Research – Human Research Program



The Human Research Program has an annual solicitation with multiple appendices for different opportunities

Open Source Science: A new model for ISS utilization

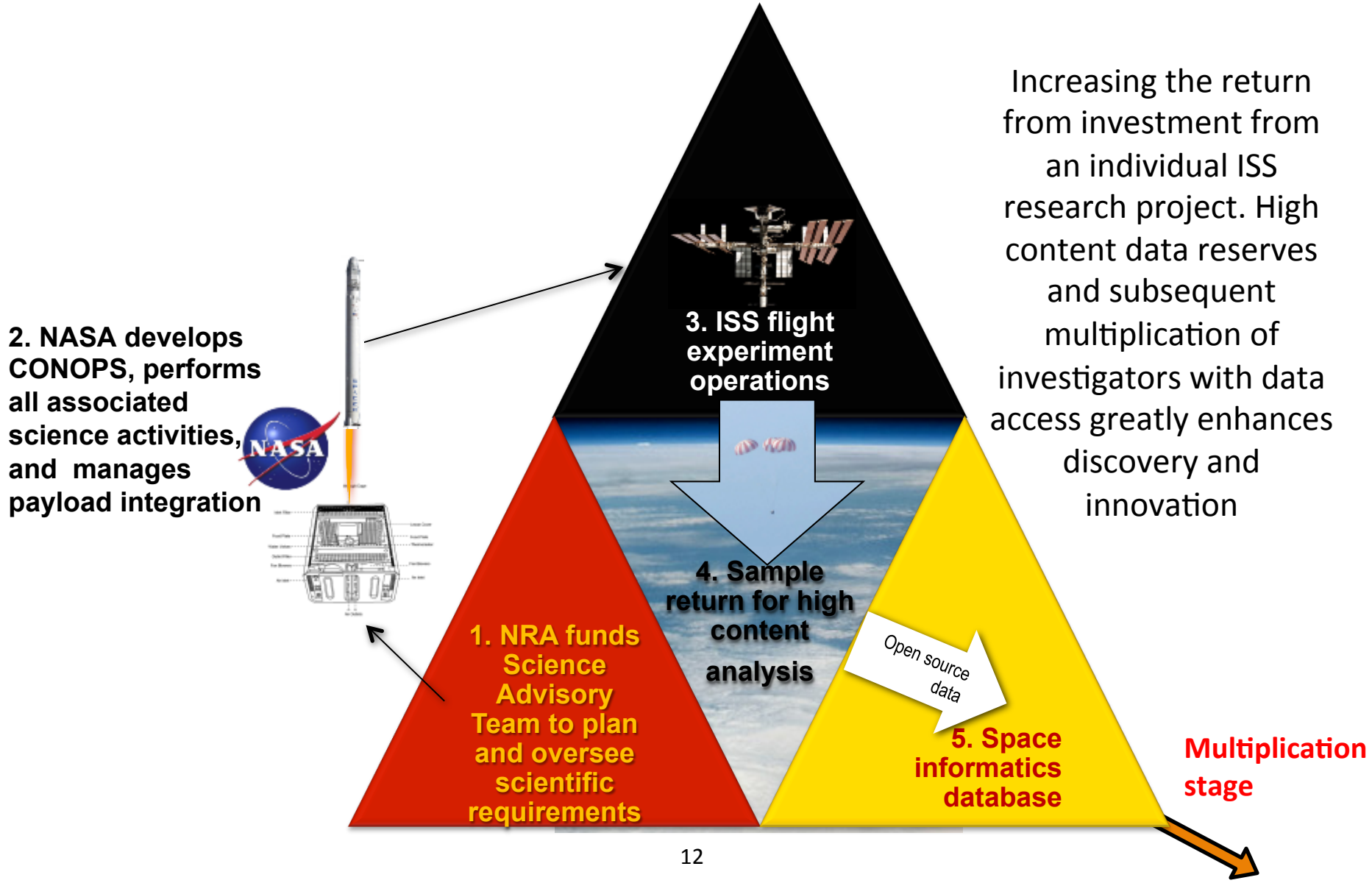
- **What currently limits ISS utilization?**
  - Funding
  - Logistics throughput
    - Up-mass, down-mass, crew time, rack availability, hardware, ground facilities, etc…
- **How do we create more PI opportunities and increase ISS utilization?**
- **Open Source Science**
  - Create multi-investigator flight experiments
  - Plan experiments based on extended arrays of data acquisition
  - Utilize high-content analytics and data collection
  - BIG data capabilities
  - Develop next-gen informatics approaches to enable discovery
    - Transform data into information-information into knowledge
  - Open up NRAs to fund 100s of PIs from a single ISS experiment
    - ISS derived data used to catalyze research to understand spaceflight

Office Of Science and Technology Policy Executive Order

"The Administration is committed to ensuring that, to the greatest extent and with the fewest constraints possible and consistent with law and the objectives set out below, the direct results of federally funded scientific research are made available to and useful for the public, industry, and the scientific community."

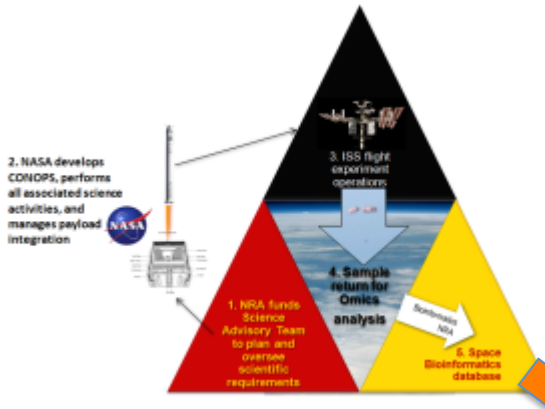
- **Agency Public Access Plan**
- **Public Access to Scientific Publications**
- **Public Access to Scientific Data in Digital Formats**

Open Source Science Campaign



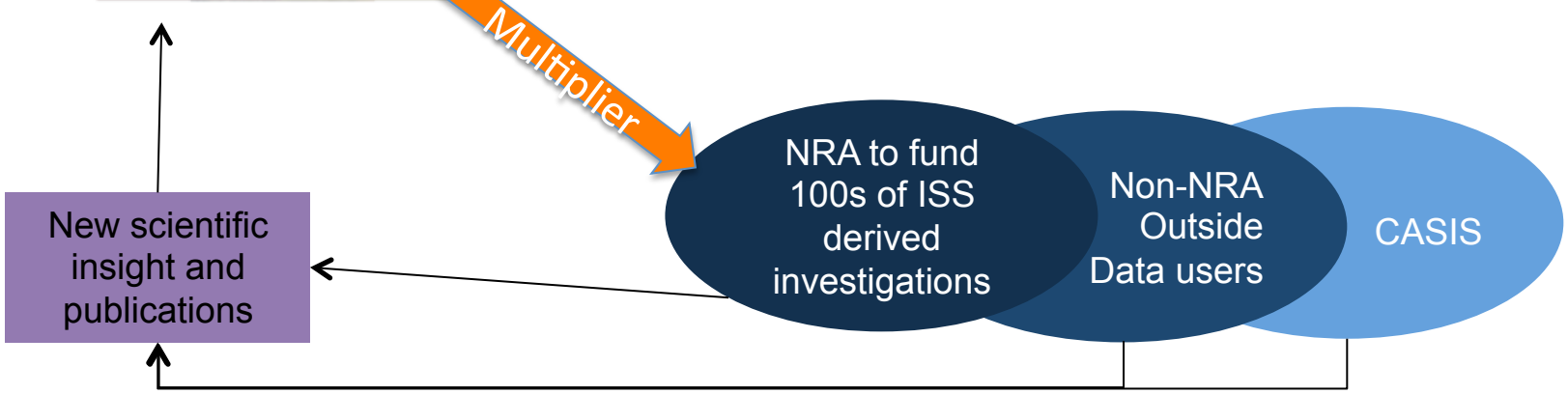
Increasing the return from investment from an individual ISS research project. High content data reserves and subsequent multiplication of investigators with data access greatly enhances discovery and innovation

Open Source Science Supports Multi-Investigator Utilization of the ISS



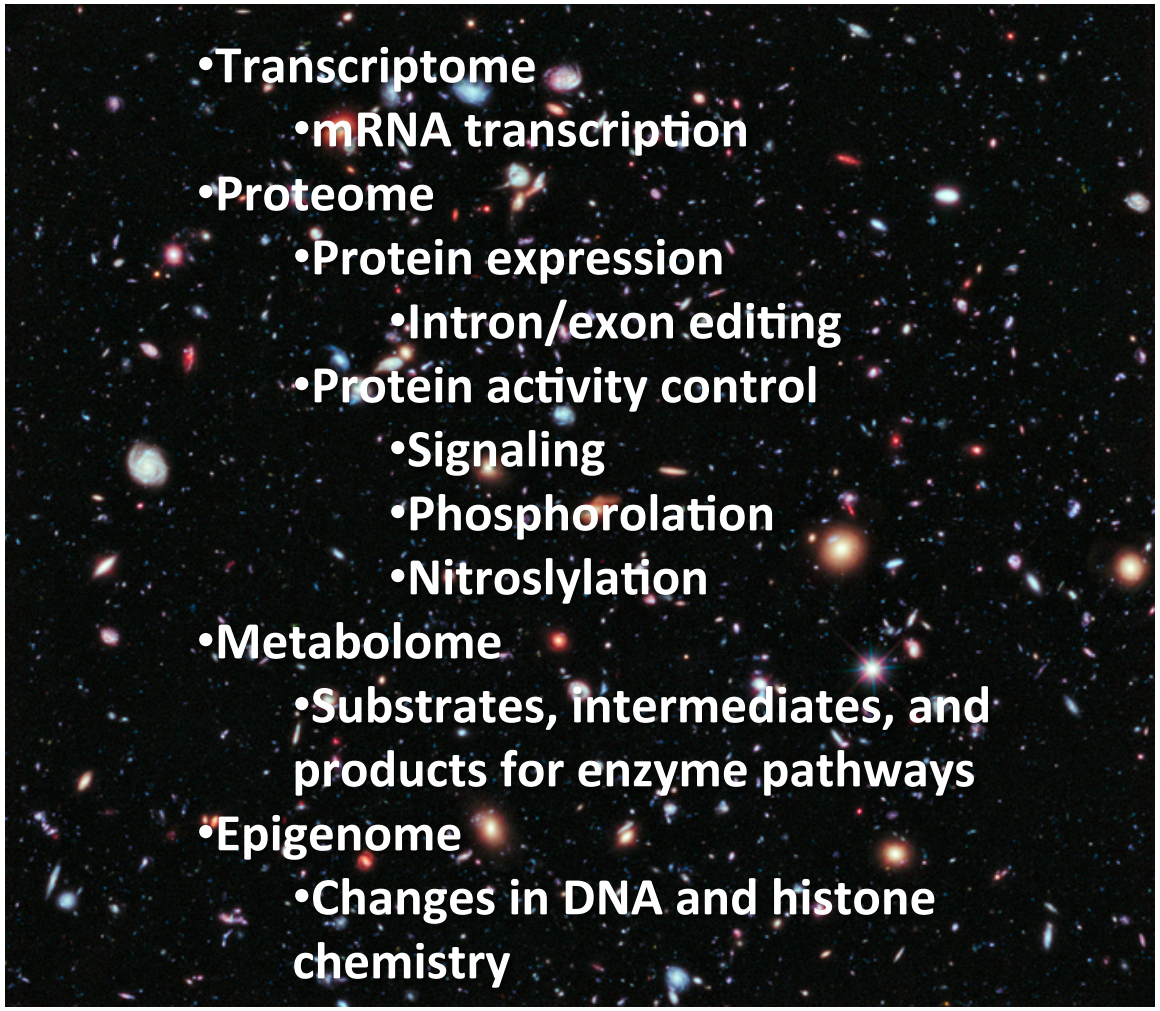
Because individual experiments are not based on individual PIs the resulting data and informatics will enable 100s of ISS investigations from a single experiment

Open-Source Science initiatives include geneLAB and materialsLAB



The Expressome as the "Telescope for Life Sciences"

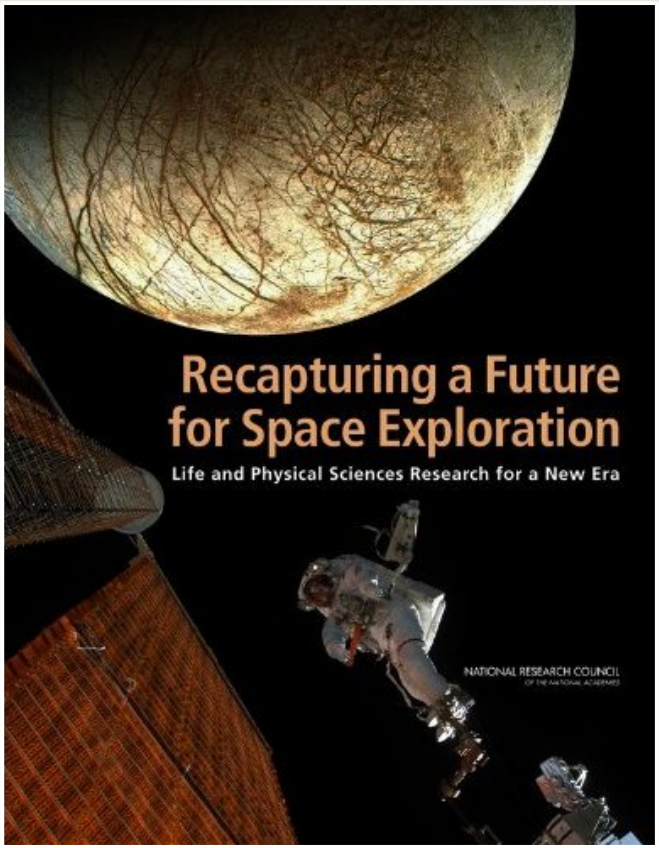
High Content Screening: as platform for high density/ high throughput life science utilization of ISS



Transcriptome
Proteome
Metabolome
\+ Epigenome
=Expressome

Excerpts from the 2010 Decadal Survey

“In the past decade, major conceptual and technological advances in genetics, molecular conservation, and genome sequencing have considerably expanded the scope and depth of developmental biology in ways that will significantly enhance the ability to uncover fundamental biological principles governing how bodies and brains organize, develop, maintain, and adapt under the constant force of gravity.”



“**High priority studies include: developmental programming, epigenetics, and omics systems biology approaches”**

“Spaceflight experiments offer unique insights in the the role of forces omnipresent on Earth (but absent in orbital flight). Such spaceflight experiments would place gravitational biology at the leading edge of modern developmental and evolutionary science”

A strategy that would benefit all research areas “Creation of robust databases that could be used for extramural scientist to address research questions”

Phased Development: 2013-2020

Phase 1
Proof of concept
2013 - 14

- Project Planning and Requirement Definition
- Methodologies Established
- Trade studies for database and sample analysis
- Baseline processes and architecture of project
- Define new analytical tools to develop

Phase 2
Ramp up, add species
2015-16

- Leverage on NRA funded investigations
- Increase experiment complexity
- Gather and incorporate lessons learned
- Develop analytical tools and models

Phase 3
Full implementation '16-20

- Full science community engagement
- Comprehensive genomics, proteomics, metabolomics, etc.
- Data-mining across platforms and species
- Apply and refine analytical tools and models

Physical Sciences – materialsLAB Open Source Science Campaign

NASA will host the **materialsLAB Workshop,** April 14-15, in the Washington, D.C., area (Hilton Crystal City Hotel, Arlington, Va).

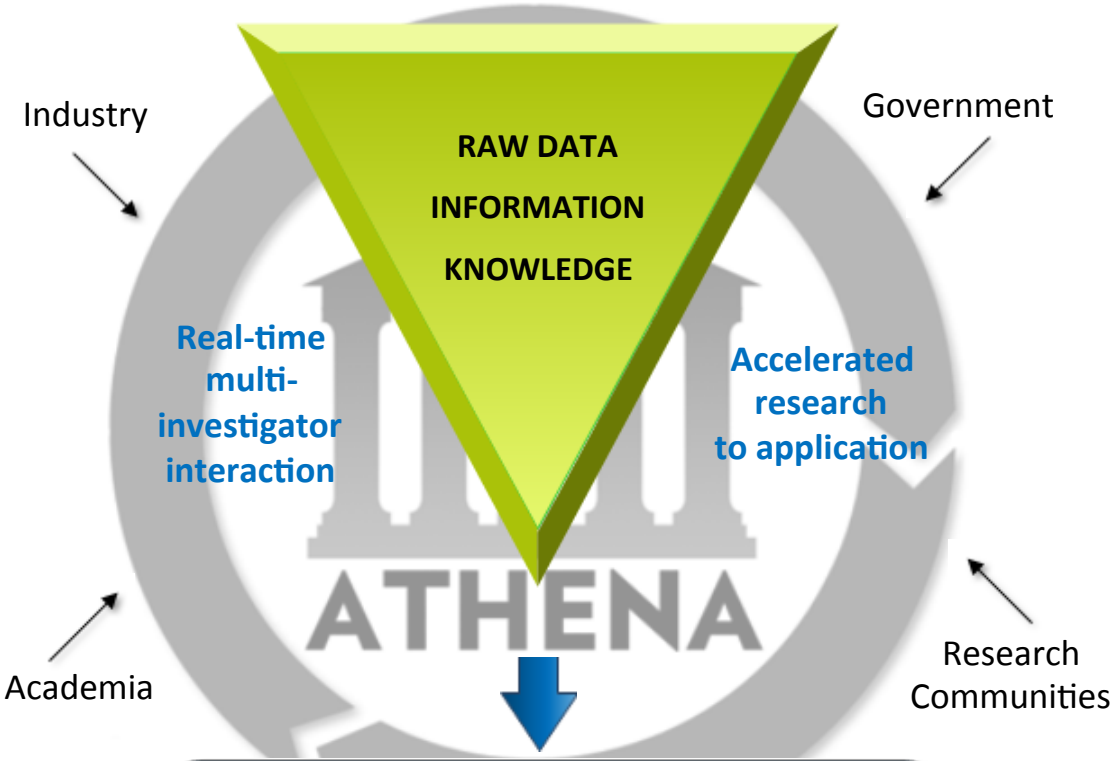
Purpose: The workshop participants will advise NASA on future research directions for the microgravity materials science program. Facilitating the future research directions, is a new *Physical Science (PS) Informatics System* that will provide global access to all past, present and future ISS PS experimental data. This will promote an open source approach to scientific data analysis and become a gateway to hundreds of new ISS-based scientific investigations that will define the next generation of ISS experiments. The subsequent multiplication of investigators with data access will greatly enhance discovery and innovation.

Theme areas: metals, semiconductors, polymers, biomaterials, nano-assembly, glasses, ceramics, granular materials, organics, composites, biomaterials and biomimetics

Websites for the materialsLAB Workshop:
Request for Information: http://tinyurl.com/mrhxt9g
Registration: http://icpi.nasaprs.com/NASAmaterialsLABWorkshop2014

ISS Physical Sciences Informatics: Overall Approach

- ISS physical sciences data contains nuggets that have the potential of high return on Agency investments.
- An **informatics system** is needed to realize return on ISS investments.
- The **informatics system** transforms the raw data obtained from ISS experiments into information that supports PI knowledge.
- The open-source **informatics system** enables real-time interactions among multiple investigators leading to research build-up, applications, and possibilities not yet realized.
- **Athena** is an informatics-ready platform



Return On Investment

- New use of ISS data
- Cost and Schedule Saving
- Research build-up & Scientific discoveries

MAPTIS: Materials and Processes Technical Information System

Open-Source-Science (OSS)

Database and pipeline to generate relevant space flight data

OSS Informatics

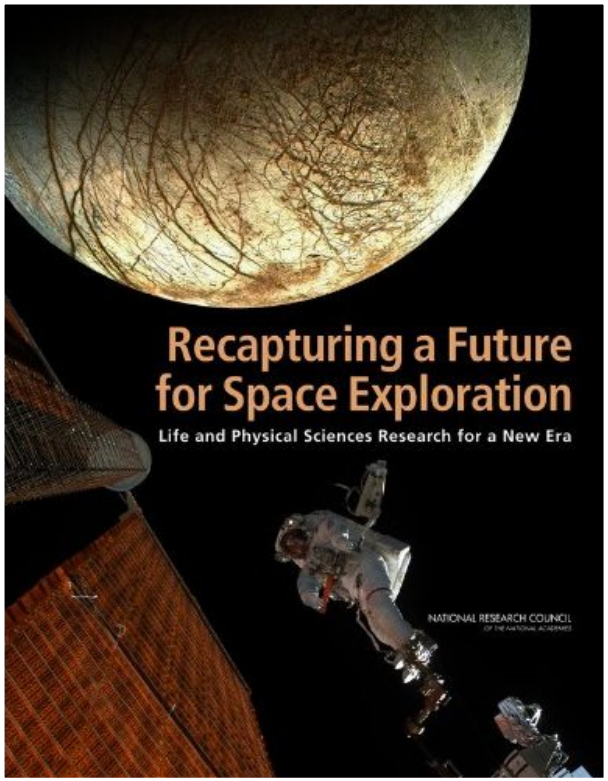
- Populated with space flight derived data
- Capable of meta-analysis across omics channels
- Highly searchable
- Linkable to existing data sets
- NRAs for ISS derivative research
- Community input and management

Pipeline for Data Collection

- Ground proof of concept
- Piggybacking on existing NRAs
- Full geneLAB missions

Response to the decadal survey: Perspectives and approaches for going forward.

- Decadal recommendations adapted into NRAs
- Support annual NRAs in Life and Physical Sciences.
- NRAs adopt “wide net” approach to attract high quality investigations and new PIs
- Planning new NRA approach for PS OSS initiatives.
- HRP expanding competent overlap with SB in animal model and OSS on ISS.
- ISLSWG and JWG focus modified to align with the Decadal and NASA OSS programs
- NAC subcommittee on Life and Physical Sciences Research is now active.
- NAS/NRC Space Studies Board being reorganized to include subcommittee for Space Biology and Physics.



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QUESTIONS?

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